

What is claimed is:

1                   1. A color characterization method for  
2 characterizing a color imaging system, the method  
3 comprising:  
4                   generating first color values in a color  
5 coordinate system by using output samples of the color  
6 imaging system, the first color values representing colors  
7 of the output samples of the color imaging system; and  
8                   converting the first color values into second  
9 color values in a device-independent color coordinate system  
10 using first and second reference values, the first reference  
11 values being adjusted using the first color values.

1                   2. A color characterization method, according to  
2 claim 1, further comprising calculating the second reference  
3 values as a function of a medium.

1                   3. A color characterization method, according to  
2 claim 2, further comprising defining the second reference  
3 values as a vector of zeros.

1                   4. A color characterization method, according to  
2 claim 2, further comprising defining the second reference

3 values using a maximum value in a black channel of the color  
4 imaging system and minimum values in at least one additional  
5 channel of the color imaging system.

1 5. A color characterization method, according to  
2 claim 2, further comprising defining the second reference  
3 values using maximum values in channels of the color imaging  
4 system.

1 6. A color characterization method, according to  
2 claim 1, further comprising calculating the first reference  
3 values using the second reference values.

1 7. A color characterization method, according to  
2 claim 1, further comprising generating the first color  
3 values using at least one of the following: a color  
4 measuring device, and a memory.

1 8. A color characterization method for  
2 characterizing a color imaging system, the method  
3 comprising:  
4 generating first color values in a color  
5 coordinate system by using output samples of the color

6 imaging system, the first color values representing colors  
7 of the output samples;  
8 converting the first color values into second  
9 color values in a device-independent color coordinate system  
10 using first and second reference values;  
11 calculating the second reference values as a  
12 function of a medium;  
13 calculating the first reference values using the  
14 second reference values; and  
15 adjusting the first reference values using the  
16 first color values.

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1 9. A color characterization method, according to  
2 claim 8, wherein the device-independent color coordinate  
3 system uses white reference tristimulus values to compensate  
4 for certain perceptual effects.

1 10. A color characterization method, according to  
2 claim 9, further comprising:  
3 converting the first color values into the second  
4 color values using transformations; and  
5 adjusting the first reference values using the  
6 first color values.

10  
1 21. A color characterization method, according to  
2 claim 8, wherein the device-independent color coordinate  
3 system is an L\*a\*b\* color coordinate system.

1 12. A color characterization method, according to  
2 claim 11, further comprising:

3 converting the first color values into the second  
4 color values using the equations

$$5 L^* = 116 \left( \frac{(Y - Y_{bp})}{(Y_n' - Y_{bp})} \right)^{1/3} - 16$$
$$6 a^* = 500 \left[ \left( \frac{(X - X_{bp})}{(X_n' - X_{bp})} \right)^{1/3} - \right.$$
$$7 \left. \left( \frac{(Y - Y_{bp})}{(Y_n' - Y_{bp})} \right)^{1/3} \right]$$
$$8 b^* = 200 \left[ \left( \frac{(Y - Y_{bp})}{(Y_n' - Y_{bp})} \right)^{1/3} - \right.$$
$$9 \left. \left( \frac{(Z - Z_{bp})}{(Z_n' - Z_{bp})} \right)^{1/3} \right],$$

10 wherein

11 X, Y, and Z are tristimulus values for the  
12 first color values,

13  $X_n'$ ,  $Y_n'$ , and  $Z_n'$  are the first reference  
14 values, and

15  $X_{bp}$ ,  $Y_{bp}$ , and  $Z_{bp}$  are the second reference  
16 values; and

17 adjusting the first reference values using the  
18 tristimulus values.

1                   13. A color characterization method, according to  
2 claim 12, further comprising adjusting the first reference  
3 values using the equations

4                    $X_n' = X_b (1 - \text{sat}(X, X_{bp}, X_n)) + X_n \cdot \text{sat}(X, X_{bp}, X_n)$

5                    $Y_n' = Y_b (1 - \text{sat}(Y, Y_{bp}, Y_n)) + Y_n \cdot \text{sat}(Y, Y_{bp}, Y_n)$

6                    $Z_n' = Z_b (1 - \text{sat}(Z, Z_{bp}, Z_n)) + Z_n \cdot \text{sat}(Z, Z_{bp}, Z_n),$

7                   wherein

8                    $\text{sat}(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$

9                    $\text{sat}(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$

10                   $\text{sat}(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$

11                   $X_n$ ,  $Y_n$ , and  $Z_n$  are tristimulus values for a perfect  
12 white diffuser under standard viewing conditions, and

13                   $X_b$ ,  $Y_b$ , and  $Z_b$  are tristimulus values for an  
14 imaging base associated with the color imaging system.

1                   14. A color characterization method, according to

2 claim 11, further comprising:

3                   converting the first color values into the second  
4 color values using the equations

5                    $L^* = 116 (Y / Y_n')^{1/3} - 16$

6                    $a^* = 500 [(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$

7                    $b^* = 200 [(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}],$

8                       wherein

9                        X, Y, and Z are tristimulus values for the

10                      first color values, and

11                       $X_n'$ ,  $Y_n'$ , and  $Z_n'$  are the first reference

12                      values; and

13                      adjusting the first reference values using the

14                      tristimulus values.

1 15. A color characterization method, according to  
2 claim 14, further comprising adjusting the first reference  
3 values using the equations

$$X_n' = X_b (1 - \text{sat}(X, X_{\max}, X_n)) + X_n \cdot \text{sat}(X, X_{\max}, X_n)$$

$$Y_n' = Y_b (1 - sat(Y, Y_{max}, Y_n)) + Y_n \cdot sat(Y, Y_{max}, Y_n)$$

$$Z_n' = Z_b (1 - \text{sat}(Z, Z_{\max}, Z_n)) + Z_n \cdot \text{sat}(Z, Z_{\max}, Z_n),$$

wherein

$$\text{sat}(X, X_{\max}, X_n) = (X - X_n) / (X_{\max} - X_n)$$

$$sat(Y, Y_{max}, Y_n) = (Y - Y_n) / (Y_{max} - Y_n)$$

$$\text{sat}(Z, Z_{\max}, Z_n) = (Z - Z_n) / (Z_{\max} - Z_n)$$

11  $X_n$ ,  $Y_n$ , and  $Z_n$  are tristimulus values for a perfect  
12 white diffuser under standard viewing conditions,

13                    $X_{\max}$ ,  $Y_{\max}$ , and  $Z_{\max}$  are tristimulus values for a  
14                   color having a maximum saturation associated with the color  
15                   imaging system, and  
16                    $X_b$ ,  $Y_b$ , and  $Z_b$  are tristimulus values for an  
17                   imaging base associated with the color imaging system.

15  
1                   16. A color characterization method, according to  
2                   claim 8, further comprising generating the first color  
3                   values using at least one of the following: a color  
4                   measuring device, and a memory.

17. For use in characterizing a color imaging  
2                   system, a color characterization arrangement comprising:  
3                   means for generating first color values in a color  
4                   coordinate system by using output samples of the color  
5                   imaging system, the first color values representing colors  
6                   of the output samples; and  
7                   means for converting the first color values into  
8                   second color values in a device-independent color coordinate  
9                   system using first and second reference values, the first  
10                   reference values being adjusted using the first color  
11                   values.

1                   18. For use in characterizing a color imaging  
2 system, a color characterization arrangement comprising:  
3                   a computer arrangement, configured and arranged to  
4 receive first color values in a color coordinate system, the  
5 first color values representing colors of output samples of  
6 the color imaging system; and  
7                   a first memory, responsive to the computer  
8 arrangement and configured and arranged to store second  
9 color values in a device-independent color coordinate  
10 system,  
11                   the computer arrangement being further configured  
12 and arranged to convert the first color values into the  
13 second color values using first and second reference values,  
14 the first reference values being adjusted using the first  
15 color values.

1                   19. A color characterization arrangement,  
2 according to claim 18, wherein the computer arrangement is  
3 further configured and arranged to calculate the second  
4 reference values as a function of a medium.

1                   20. A color characterization arrangement,  
2 according to claim 19, wherein the computer arrangement is

3 further configured and arranged to define the second  
4 reference values as a vector of zeros.

1 21. A color characterization arrangement,  
2 according to claim 19, wherein the computer arrangement is  
3 further configured and arranged to define the second  
4 reference values using a maximum value in a black channel of  
5 the color imaging system and minimum values in at least one  
6 additional channel of the color imaging system.

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1 22. A color characterization arrangement,  
2 according to claim 19, wherein the computer arrangement is  
3 further configured and arranged to define the second  
4 reference values using maximum values in channels of the  
5 color imaging system.

1 23. A color characterization arrangement,  
2 according to claim 18, wherein the computer arrangement is  
3 further configured and arranged to calculate the first  
4 reference values using the second reference values.

1 24. A color characterization arrangement,  
2 according to claim 18, wherein the computer arrangement is

3 further configured and arranged to adjust the first  
4 reference values using the first color values.

5 25. A color characterization arrangement,  
6 according to claim 18, wherein the device-independent color  
7 coordinate system uses white reference tristimulus values to  
8 compensate for certain perceptual effects.

1 26. A color characterization arrangement,  
2 according to claim 18, wherein the computer arrangement is  
3 further configured and arranged to:  
4 convert the first color values into the second  
5 color values using transformations; and  
6 adjust the first reference values using the first  
7 color values.

1 27. A color characterization arrangement,  
2 according to claim 18, wherein the device-independent color  
3 coordinate system is an  $L^*a^*b^*$  color coordinate system.

1 28. A color characterization arrangement,  
2 according to claim 27, wherein the computer arrangement is  
3 further configured and arranged to:

4 convert the first color values into the second  
5 color values using the equations

6  $L^* = 116 ((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - 16$

7  $a^* = 500 [((X - X_{bp}) / (X_n' - X_{bp}))^{1/3} -$   
8  $((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3}]$

9  $b^* = 200 [((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} -$   
10  $((Z - Z_{bp}) / (Z_n' - Z_{bp}))^{1/3}]$ ,

11 wherein

12  $X$ ,  $Y$ , and  $Z$  are tristimulus values for the  
13 first color values,

14  $X_n'$ ,  $Y_n'$  and  $Z_n'$  are the first reference  
15 values, and

16  $X_{bp}$ ,  $Y_{bp}$ , and  $Z_{bp}$  are the second reference  
17 values; and

18 adjust the first reference values using the  
19 tristimulus values.

1 29. A color characterization arrangement,  
2 according to claim 28, wherein the computer arrangement is  
3 further configured and arranged to adjust the first  
4 reference values using the equations

5  $X_n' = X_b / (1 - \text{sat}(X, X_{bp}, X_n)) + X_n \cdot \text{sat}(X, X_{bp}, X_n)$

6  $Y_n' = Y_b (1 - \text{sat}(Y, Y_{bp}, Y_n)) + Y_n \cdot \text{sat}(Y, Y_{bp}, Y_n)$

7  $Z_n' = Z_b (1 - \text{sat}(Z, Z_{bp}, Z_n)) + Z_n \cdot \text{sat}(Z, Z_{bp}, Z_n),$

8 wherein

9  $\text{sat}(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$

10  $\text{sat}(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$

11  $\text{sat}(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$

12 *X<sub>n</sub>, Y<sub>n</sub>, and Z<sub>n</sub> are tristimulus values for a perfect*

13 *white diffuser under standard viewing conditions, and*

14 *X<sub>b</sub>, Y<sub>b</sub>, and Z<sub>b</sub> are tristimulus values for an*

15 *imaging base associated with the color imaging system.*

1 30. A color characterization arrangement,

2 according to claim 27, wherein the computer arrangement is

3 further configured and arranged to:

4 convert the first color values into the second

5 color values using the equations

6  $L^* = 116(Y / Y_n')^{1/3} - 16$

7  $a^* = 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$

8  $b^* = 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}],$

9 wherein

10 *X, Y, and Z are tristimulus values for the*

11 *first color values, and*

12                    $X_n'$ ,  $Y_n'$ , and  $Z_n'$  are the first reference  
13   values; and

14                   adjust the first reference values using the  
15   tristimulus values.

1                   31. A color characterization arrangement,

2   according to claim 30, wherein the computer arrangement is  
3   further configured and arranged to adjust the first  
4   reference values using the equations

5                    $X_n' = X_b(1 - \text{sat}(X, X_{\max}, X_n)) + X_n \cdot \text{sat}(X, X_{\max}, X_n)$

6                    $Y_n' = Y_b(1 - \text{sat}(Y, Y_{\max}, Y_n)) + Y_n \cdot \text{sat}(Y, Y_{\max}, Y_n)$

7                    $Z_n' = Z_b(1 - \text{sat}(Z, Z_{\max}, Z_n)) + Z_n \cdot \text{sat}(Z, Z_{\max}, Z_n)$ ,

8                   wherein

9                    $\text{sat}(X, X_{\max}, X_n) = (X - X_n) / (X_{\max} - X_n)$

10                    $\text{sat}(Y, Y_{\max}, Y_n) = (Y - Y_n) / (Y_{\max} - Y_n)$

11                    $\text{sat}(Z, Z_{\max}, Z_n) = (Z - Z_n) / (Z_{\max} - Z_n)$

12                    $X_n$ ,  $Y_n$ , and  $Z_n$  are tristimulus values for a perfect  
13   white diffuser under standard viewing conditions,

14                    $X_{\max}$ ,  $Y_{\max}$ , and  $Z_{\max}$  are tristimulus values for a  
15   color having a maximum saturation associated with the color  
16   imaging system, and

17

~~$X_b$ ,  $Y_b$ , and  $Z_b$  are tristimulus values for an~~

18

imaging base associated with the color imaging system.

1

<sup>28</sup> 32. A color characterization arrangement,

2

according to claim <sup>17</sup> 18, further comprising a second memory,

3

configured and arranged to provide the first color values to

4

the computer arrangement.

1

<sup>29</sup> 33. A color characterization arrangement,

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according to claim <sup>17</sup> 18, further comprising a color measuring

3

instrument, configured and arranged to:

4

obtain the first color values from a sample; and

5

provide the first color values to the computer

6

arrangement.

1

34. For use in characterizing a color imaging

2

system, a data storage medium storing a computer-executable

3

program configured and arranged to, when executed,

4

obtain first color values in a color coordinate

5

system by using output samples of the color imaging system,

6

the first color values representing colors of the output

7

samples, and

8 convert the first color values into second color  
9 values in a device-independent color coordinate system using  
10 first and second reference values, the first reference  
11 values being adjusted using the first color values.

1 35. A data storage medium, according to claim 34,  
2 wherein the computer-executable program is further  
3 configured and arranged to, when executed, calculate the  
4 second reference values as a function of a medium.

1 36. A data storage medium, according to claim 35,  
2 wherein the computer-executable program is configured and  
3 arranged to, when executed, define the second reference  
4 values as a vector of zeros.

1 37. A data storage medium, according to claim 35,  
2 wherein the computer-executable program is configured and  
3 arranged to, when executed, define the second reference  
4 values using a maximum value in a black channel of the color  
5 imaging system and minimum values in at least one additional  
6 channel of the color imaging system.

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1           38. A data storage medium, according to claim 35,  
2   wherein the computer-executable program is configured and  
3   arranged to, when executed, define the second reference  
4   values using maximum values in channels of the color imaging  
5   system.

Sub  
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1           39. A data storage medium, according to claim 34,  
2   wherein the computer-executable program is further  
3   configured and arranged to, when executed, calculate the  
4   first reference values using the second reference values.

Sub  
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7

1           40. A data storage medium, according to claim 34,  
2   wherein the computer-executable program is further  
3   configured and arranged to, when executed, adjust the first  
4   reference values using the first color values.

Sub  
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7

1           41. A data storage medium, according to claim 34,  
2   wherein the device-independent color coordinate system uses  
3   white reference tristimulus values to compensate for certain  
4   perceptual effects.

1                   42. A data storage medium, according to claim 41,  
2 wherein the computer-executable program is further  
3 configured and arranged to, when executed,  
4 convert the first color values into the second  
5 color values using transformations; and  
6 adjust the first reference values using the first  
7 color values.

1                   31                   30  
2                   43. A data storage medium, according to claim 34,  
3 wherein the device-independent color coordinate system is an  
4  $L^*a^*b^*$  color coordinate system.

1                   44. A data storage medium, according to claim 43,  
2 wherein the computer-executable program is further  
3 configured and arranged to, when executed,  
4 convert the first color values into the second  
5 color values using the equations

$$6 \quad L^* = 116 \left( \frac{(Y - Y_{bp})}{(Y_n' - Y_{bp})} \right)^{1/3} - 16$$
$$7 \quad a^* = 500 \left[ \left( \frac{(X - X_{bp})}{(X_n' - X_{bp})} \right)^{1/3} - \right. \\ \left. \left( \frac{(Y - Y_{bp})}{(Y_n' - Y_{bp})} \right)^{1/3} \right]$$
$$8 \quad b^* = 200 \left[ \left( \frac{(Y - Y_{bp})}{(Y_n' - Y_{bp})} \right)^{1/3} - \right. \\ \left. \left( \frac{(Z - Z_{bp})}{(Z_n' - Z_{bp})} \right)^{1/3} \right],$$

1 45. A data storage medium, according to claim 44,  
2 wherein the computer-executable program is further  
3 configured and arranged to, when executed, adjust the first  
4 reference values using the equations

$$X_n' = X_b (1 - \text{sat}(X, X_{bp}, X_n)) + X_n \cdot \text{sat}(X, X_{bp}, X_n)$$

$$Y_n' = Y_b (1 - sat(Y, Y_{bp}, Y_n)) + Y_n \cdot sat(Y, Y_{bp}, Y_n)$$

$$Z_n' = Z_b (1 - sat(Z, Z_{bp}, Z_n)) + Z_n \cdot sat(Z, Z_{bp}, Z_n),$$

8 wherein

$$\text{sat}(X, X_{\text{bp}}, X_n) = (X - X_n) / (X_{\text{bp}} - X_n)$$

$$\text{sat}(Y, Y_{bp}, Y_n) = (Y \neq Y_n) / (Y_{bp} - Y_n)$$

$$\text{sat}(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$$

12                    $X_n$ ,  $Y_n$ , and  $Z_n$  are tristimulus values for a perfect  
13 white diffuser under standard viewing conditions, and  
14                    $X_b$ ,  $Y_b$ , and  $Z_b$  are tristimulus values for an  
15 imaging base associated with the color imaging system.

1                   46. A data storage medium, according to claim 43,  
2 wherein the computer-executable program is further  
3 configured and arranged to, when executed,  
4                   convert the first color values into the second  
5 color values using the equations

$$L^* = 116(Y / Y_n')^{1/3} - 16$$

$$a^* = 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$$

$$b^* = 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}],$$

9                   wherein

10                    $X$ ,  $Y$ , and  $Z$  are tristimulus values for the  
11 first color values, and

12                    $X_n'$ ,  $Y_n'$ , and  $Z_n'$  are the first reference  
13 values, and

14                   adjust the first reference values using the  
15 tristimulus values.

1                   47. A data storage medium, according to claim 46,  
2    wherein the computer-executable program is further  
3    configured and arranged to, when executed, adjust the first  
4    reference values using the equations

5                    $X_n' = X_b(1 - \text{sat}(X, X_{\max}, X_n)) + X_n \cdot \text{sat}(X, X_{\max}, X_n)$

6                    $Y_n' = Y_b(1 - \text{sat}(Y, Y_{\max}, Y_n)) + Y_n \cdot \text{sat}(Y, Y_{\max}, Y_n)$

7                    $Z_n' = Z_b(1 - \text{sat}(Z, Z_{\max}, Z_n)) + Z_n \cdot \text{sat}(Z, Z_{\max}, Z_n)$ ,

8                   wherein

9                    $\text{sat}(X, X_{\max}, X_n) = (X - X_n) / (X_{\max} - X_n)$

10                   $\text{sat}(Y, Y_{\max}, Y_n) = (Y - Y_n) / (Y_{\max} - Y_n)$

11                   $\text{sat}(Z, Z_{\max}, Z_n) = (Z - Z_n) / (Z_{\max} - Z_n)$

12                   $X_n$ ,  $Y_n$ , and  $Z_n$  are tristimulus values for a perfect

13                  white diffuser under standard viewing conditions,

14                   $X_{\max}$ ,  $Y_{\max}$ , and  $Z_{\max}$  are tristimulus values for a

15                  color having a maximum saturation associated with the color

16                  imaging system, and

17                   $X_b$ ,  $Y_b$ , and  $Z_b$  are tristimulus values for an

18                  imaging base associated with the color imaging system.

1                   48. A data storage medium, according to claim 34,

2    wherein the computer-executable program is further

3 configured and arranged to, when executed, store the second  
4 color values in a memory.

1 49. A color transformation method for performing  
2 a color transformation between first and second color  
3 imaging systems, the color transformation method comprising:

4 generating first and second color values by using  
5 output samples of the first and second color imaging  
6 systems, the first and second color values respectively  
7 representing colors of the output samples of the first and  
8 second color imaging systems;

9 converting the first and second color values  
10 respectively into third and fourth color values using a  
11 device-independent color coordinate system;

12 calculating first reference values from a medium  
13 and second reference values from the first reference values;

14 adjusting the second reference values using the  
15 first and second color values; and

16 generating color transformation values using the  
17 third and fourth color values.

1 50. A color characterization method, according to  
2 claim 49, wherein the device-independent color coordinate

3 system uses white reference tristimulus values to compensate  
4 for certain perceptual effects.

1 51. A color characterization method, according to  
2 claim 50, further comprising:  
3 converting the first color values into the second  
4 color values using transformations; and  
5 adjusting the first reference values using the  
6 first color values.

1 46  
2 52. A color transformation method, according to  
3 claim 49, wherein the color coordinate system is an L\*a\*b\*  
4 color coordinate system.

1 53. A color transformation method, according to  
2 claim 52, further comprising:  
3 converting the first color values into the third  
4 color values using the equations

$$5 L^* = 116 \left( \left( Y_1 - Y_{bp1} \right) / \left( Y_{n1}' - Y_{bp1} \right) \right)^{1/3} - 16$$
$$6 a^* = 500 \left[ \left( \left( X_1 - X_{bp1} \right) / \left( X_{n1}' - X_{bp1} \right) \right)^{1/3} - \right.$$
$$7 \left. \left( \left( Y_1 - Y_{bp1} \right) / \left( Y_{n1}' - Y_{bp1} \right) \right)^{1/3} \right]$$
$$8 b^* = 200 \left[ \left( \left( Y_1 - Y_{bp1} \right) / \left( Y_{n1}' - Y_{bp1} \right) \right)^{1/3} - \right.$$
$$9 \left. \left( \left( Z_1 - Z_{bp1} \right) / \left( Z_{n1}' - Z_{bp1} \right) \right)^{1/3} \right],$$

$$\begin{aligned}
 L^* &= 116 ((Y_2 - Y_{bp2}) / (Y_{n2}' - Y_{bp2}))^{1/3} - 16 \\
 a^* &= 500 [((X_2 - X_{bp2}) / (X_{n2}' - X_{bp2}))^{1/3} - \\
 &\quad ((Y_2 - Y_{bp2}) / (Y_{n2}' - Y_{bp2}))^{1/3}] \\
 b^* &= 200 [((Y_2 - Y_{bp2}) / (Y_{n2}' - Y_{bp2}))^{1/3} - \\
 &\quad ((Z_2 - Z_{bp2}) / (Z_{n2}' - Z_{bp2}))^{1/3}]
 \end{aligned}$$

wherein

$X_2$ ,  $Y_2$ , and  $Z_2$  are tristimulus values for the color values,

$X_{bp2}$ ,  $Y_{bp2}$ , and  $Z_{bp2}$  are black tristimulus for the second color imaging system, and

$X_{n2}'$ ,  $Y_{n2}'$ , and  $Z_{n2}'$  are white tristimulus for the second color imaging system; and

1                    54. A color transformation method, according to  
2 claim 53, further comprising:

$$X_{n1}' = X_{b1} (1 - \text{sat}(X_1, X_{bp1}, X_{n1})) + X_{n1} \cdot$$

$$6 \qquad \qquad \qquad \text{sat}(X_1, X_{\text{bp1}}, X_{\text{n1}})$$

$$Y_{n1}' = Y_{b1}(1 - sat(Y_1, Y_{bp1}, Y_{n1})) + Y_{n1} \cdot$$

8  $\text{sat}(\mathbf{Y}_1, \mathbf{Y}_{\text{bp1}}, \mathbf{Y}_{\text{n1}})$

$$Z_{n1} = Z_{b1}(1 - \text{sat}(Z_1, Z_{bp1}, Z_{n1})) + Z_{n1}$$

$$10 \qquad \qquad \qquad \text{sat}(Z_1, Z_{bp1}, Z_{n1}) \, ,$$

11 wherein

$$12 \qquad \qquad \qquad \text{sat}(X_1, X_{bp}, X_n) = (X_1 - X_{n1}) / (X_{bp1} - X_{n1})$$

$$13 \quad \text{sat}(Y_1, Y_{bp}, Y_n) = (Y_1 - Y_{n1}) / (Y_{bp1} - Y_{n1})$$

$$14 \qquad \qquad \qquad \text{sat}(Z_1, Z_{bp1}, Z_{n1}) = (Z_1 - Z_{n1}) / (Z_{bp1} - Z_{n1})$$

15                            $X_{n1}$ ,  $Y_{n1}$ , and  $Z_{n1}$  are tristimulus values for a  
16   perfect white diffuser associated with the first color  
17   imaging system under standard viewing conditions, and

18                    $X_{b1}$ ,  $Y_{b1}$ , and  $Z_{b1}$  are tristimulus values for an  
19   imaging base associated with the first color imaging system;  
20   and

21                   adjusting the white reference tristimulus values  
22   for the second color imaging system using the equations

23                    $X_{n2}' = X_{b2}(1 - \text{sat}(X_2, X_{bp2}, X_{n2})) + X_{n2}$

24                    $\text{sat}(X_2, X_{bp2}, X_{n2})$

25                    $Y_{n2}' = Y_{b2}(1 - \text{sat}(Y_2, Y_{bp2}, Y_{n2})) + Y_{n2}$

26                    $\text{sat}(Y_2, Y_{bp2}, Y_{n2})$

27                    $Z_{n2}' = Z_{b2}(1 - \text{sat}(Z_2, Z_{bp2}, Z_{n2})) + Z_{n2}$

28                    $\text{sat}(Z_2, Z_{bp2}, Z_{n2})$ ,

29                   wherein

30                    $\text{sat}(X_2, X_{bp}, X_n) = (X_2 - X_{n2}) / (X_{bp2} - X_{n2})$

31                    $\text{sat}(Y_2, Y_{bp}, Y_n) = (Y_2 - Y_{n2}) / (Y_{bp2} - Y_{n2})$

32                    $\text{sat}(Z_2, Z_{bp2}, Z_{n2}) = (Z_2 - Z_{n2}) / (Z_{bp2} - Z_{n2})$

33                    $X_{n2}$ ,  $Y_{n2}$ , and  $Z_{n2}$  are tristimulus values for a

34   perfect white diffuser associated with the second color

35   imaging system under standard viewing conditions, and

36                    $X_{b2}$ ,  $Y_{b2}$ , and  $Z_{b2}$  are tristimulus values for an

37   imaging base associated with the second color imaging

38   system.

1                   55. A color characterization method, according to  
2 claim 52, further comprising:

3                   converting the first color values into the third  
4 color values using the equations

5                    $L^* = 116(Y_1 / Y_{n1}')^{1/3} - 16$

6                    $a^* = 500[(X_1 / X_{n1}')^{1/3} - (Y_1 / Y_{n1}')^{1/3}]$

7                    $b^* = 200[(Y_1 / Y_{n1}')^{1/3} - (Z_1 / Z_{n1}')^{1/3}]$ ,

8                   wherein

9                    $X_1$ ,  $Y_1$ , and  $Z_1$  are tristimulus values for the  
10 first color values, and

11                    $X_{n1}'$ ,  $Y_{n1}'$ , and  $Z_{n1}'$  are white reference  
12 tristimulus values for the first color imaging system;

13                   converting the second color values into the fourth  
14 color values using the equations

15                    $L^* = 116(Y_2 / Y_{n2}')^{1/3} - 16$

16                    $a^* = 500[(X_2 / X_{n2}')^{1/3} - (Y_2 / Y_{n2}')^{1/3}]$

17                    $b^* = 200[(Y_2 / Y_{n2}')^{1/3} - (Z_2 / Z_{n2}')^{1/3}]$ ,

18                   wherein

19                    $X_2$ ,  $Y_2$ , and  $Z_2$  are tristimulus values for the  
20 second color values, and

21                    $X_{n2}'$ ,  $Y_{n2}'$ , and  $Z_{n2}'$  are white reference  
22 tristimulus values for the second color imaging system; and

1                    86. A color transformation method, according to  
2                    49 claim 55, further comprising:

5                    $X_{n1}' = X_{b1}(1 - sat(X_1, X_{max1}, X_{n1})) +$   
 6                    $X_{n1} \cdot sat(X_1, X_{max1}, X_{n1})$

7                    $Y_{n1}' = Y_{b1}(1 - sat(Y_1, Y_{max1}, Y_{n1})) +$   
 8                    $Y_{n1} : sat(Y_1, Y_{max1}, Y_{n1})$

9                    $Z_{n1}' = Z_{b1}(1 - \text{sat}(Z_1, Z_{\max 1}, Z_{n1})) +$   
 .0                    $Z_{n1} \cdot \text{sat}(Z_1, Z_{\max 1}, Z_{n1}),$

-1 wherein

$$-2 \quad \text{sat}(X_1, X_{\max 1}, X_{n1}) = (X_1 - X_{n1}) / (X_{\max 1} - X_{n1})$$

$$13 \quad \text{sat}(Y_1, Y_{\max 1}, Y_{n1}) = (Y_1 - Y_{n1}) / (Y_{\max 1} - Y_{n1})$$

$$14 \quad \text{sat}(Z_1, Z_{\max 1}, Z_{n1}) = (Z_1 - Z_{n1}) / (Z_{\max 1} - Z_{n1})$$

15                    $X_{n1}$ ,  $Y_{n1}$ , and  $Z_{n1}$  are tristimulus values for a  
16 perfect white diffuser associated with the first color  
17 imaging system under standard viewing conditions,

18                    $X_{max1}$ ,  $Y_{max1}$ , and  $Z_{max1}$  are tristimulus values for a  
19   color having a maximum saturation associated with the first  
20   color imaging system, and

21                    $X_{b1}$ ,  $Y_{b1}$ , and  $Z_{b1}$  are tristimulus values for an  
22   imaging base associated with the first color imaging system;  
23   and

24                   adjusting the white reference tristimulus values  
25   for the second color imaging system using the equations

26                    $X_{n2}' = X_{b2}(1 - sat(X_2, X_{max2}, X_{n2})) +$

27                    $X_{n2} \cdot sat(X_2, X_{max2}, X_{n2})$

28                    $Y_{n2}' = Y_{b2}(1 - sat(Y_2, Y_{max2}, Y_{n2})) +$

29                    $Y_{n2} \cdot sat(Y_2, Y_{max2}, Y_{n2})$

30                    $Z_{n2}' = Z_{b2}(1 - sat(Z_2, Z_{max2}, Z_{n2})) +$

31                    $Z_{n2} \cdot sat(Z_2, Z_{max2}, Z_{n2})$ ,

32                   wherein

33                    $sat(X_2, X_{max2}, X_{n2}) = (X_2 - X_{n2}) / (X_{max2} - X_{n2})$

34                    $sat(Y_2, Y_{max2}, Y_{n2}) = (Y_2 - Y_{n2}) / (Y_{max2} - Y_{n2})$

35                    $sat(Z_2, Z_{max2}, Z_{n2}) = (Z_2 - Z_{n2}) / (Z_{max2} - Z_{n2})$

36                    $X_{n2}$ ,  $Y_{n2}$ , and  $Z_{n2}$  are tristimulus values for a  
37   perfect white diffuser associated with the second color  
38   imaging system under standard viewing conditions,

39                    $X_{\max 2}$ ,  $Y_{\max 2}$ , and  $Z_{\max 2}$  are tristimulus values for a  
40   color having a maximum saturation associated with the second  
41   color imaging system, and  
42                    $X_{b2}$ ,  $Y_{b2}$ , and  $Z_{b2}$  are tristimulus values for an  
43   imaging base associated with the second color imaging  
44   system.

1                   57. For use in performing a color transformation  
2   between first and second color imaging systems, a color  
3   transformation arrangement comprising:  
4                   means for generating first color values by using  
5   output samples of the first color imaging system, the first  
6   color values representing colors of the output samples of  
7   the first color imaging system;  
8                   means for generating second color values by using  
9   output samples of the second color imaging system, the  
10   second color values representing colors of the output  
11   samples of the second color imaging system;  
12                   means for converting the first color values into  
13   third color values using a color coordinate system;  
14                   means for converting the second color values into  
15   fourth color values using the color coordinate system;

16 means for calculating first reference values from  
17 a medium and second reference values from the first  
18 reference values;  
19 means for adjusting the second reference values  
20 using the first and second color values; and  
21 means for generating color transformation values  
22 using the third and fourth color values.

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